SUPPLY CHAIN TRANSFORMATION:
AN INFORMATION TECHNOLOGY PERSPECTIVE

THESIS

Jessica A. Smith

AFIT-ENS-MS-17-S-065

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

WRIGHT-PATTERSON AIR FORCE BASE, OHIO

AFIT-ENS-MS-17-S-065

SUPPLY CHAIN TRANSFORMATION: AN INFORMATION TECHNOLOGY PERSPECTIVE

THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics & Supply Chain Management

Jessica A. Smith

September 2017

AFIT-ENS-MS-17-S-065

**SUPPLY CHAIN TRANSFORMATION:
AN INFORMATION TECHNOLOGY PERSPECTIVE**

Jessica A. Smith

Committee Membership:

Dr. Paul Hartman

Advisor

Dr. Alan Johnson

Reader

Abstract

Since the early 2000s, the U.S. Air Force Logistics Community has invested in multiple high-level strategic programs and related information technology (IT) initiatives in attempt to significantly improve global supply chain practices. Unfortunately, strategic programs such as the Expeditionary Logistics for the 21st Century and its associated initiatives had limited success and failed to produce desired improvements. In order to remain competitive in the evolving global warfighting environment and to fulfill Third Offset requirements, it is important for the U.S. Air Force Logistics Community to use lessons-learned in its own IT-enabled supply chain transformation history, as well as industry best practices and lessons-learned to effectively harness the power of advanced information technologies.

The purpose of this research is to examine U.S. Air Force and industry supply chain IT-enabled transformations to identify critical factors for the successful adoption of new supply chain technologies. Based on the findings from a review of existing literature and semi-structured interviews with eleven subject matter experts, four propositions have been developed as a suggested framework for the U.S. Air Force Logistics Community to consider when evaluating potential supply chain-related information technology initiatives. The four propositions were identified as important aspects for successful IT implementation by literature and selected interviewees regarding policy, workforce education, investment, and industry collaboration.

Acknowledgements

I would like to express my most sincere appreciation to my fellow classmates and all AFIT faculty and staff members that supported me throughout the course of this thesis effort. A special thank you to my research advisor, Dr Paul Hartman, and thesis reader, Dr Alan Johnson, for the guidance and invaluable insight they provided me. I would also like to thank my sponsor, Ms Kim Brown, from the Air Force Materiel Command, for the support she provided me in this endeavor.

Jessica A. Smith

Table of Contents

Abstract v

Acknowledgements vi

Table of Contents vii

List of Figures x

I. Introduction 11

Background 11

IT-related U.S. Air Force Supply Chain Initiatives 12

IT-related Industry Supply Chain Initiatives 14

Motivation 16

Problem Statement 17

Purpose Statement 18

Research Questions 18

Scope 19

II. Literature Review 20

Expeditionary Logistics for the 21st Century 20

Expeditionary Combat Support System 23

Purchasing and Supply Chain Management 25

Logistics Enterprise Architecture 26

Condition Based Maintenance Plus 27

Industry 28

Theoretical Development 31

III. Methodology ... 35
Data Collection Method ... 36
Interviewee Sampling Strategy ... 36
Panel Member Interviews ... 37
Data Analysis Method ... 39
IV. Results and Analysis ... 40
IIoT Summit Notable Results ... 40
Participant A ... 40
Participant B ... 41
Participant C ... 41
Participant D ... 42
Participant E ... 43
Analysis ... 44
V. Conclusions and Recommendations ... 45
Conclusions ... 45
Research Question #1 ... 45
Research Question #2 ... 45
Research Question #3 ... 46
Policy ... 46
Workforce Education ... 47
Investment ... 49
Industry Collaboration ... 50
Validity of Theory Selection ... 52

Air Force Implications 52

Further Research Opportunities 53

APPENDIX A 54

APPENDIX B 55

APPENDIX C 56

APPENDIX D 57

APPENDIX E 58

APPENDIX F 61

APPENDIX G 62

Bibliography 65

List of Figures

Figure 1. Lean Manufacturing Practices..21

Figure 2. Sample Defect Rate at Six Sigma Levels 22

Figure 3. Everette Rogers Rate of Adoption Curve...33

Figure 4. Years of Professional Experience – IIoT Summit Panel Members 38

Figure 5. Critical Factors for Successful Implementation of Enterprise Systems 46

Figure 6. SAF/CIO A6 Information Dominance Vision..49

Figure 7. Federal Chief Data Officer Information 51

SUPPLY CHAIN TRANSFORMATION: AN INFORMATION TECHNOLOGY PERSPECTIVE

I. INTRODUCTION

Background

Since the early 2000s, the U.S. Air Force Logistics Community has invested in multiple high-level strategic programs and related information technology (IT) initiatives in an attempt to significantly improve global supply chain practices. The Information Technology Association of America defines IT as the capability to electronically input, process, store, output, transmit, and receive data and information, including text, graphics, sound, and video, as well as the ability to control machines of all kinds electronically (Carroll et al., 2008). Now that more prevalent amounts of data and related analysis capabilities exist, the Department of Defense (DoD) and U.S. Air Force have put into place policies and initiatives such as the 2014 *Third Offset Strategy* to embrace technology and harness the power of data.

Unfortunately, strategic programs such as the Expeditionary Logistics for the 21st Century (eLog21) and its associated initiatives had limited success and failed to produce desired improvements. In order to remain competitive in the evolving, global warfighting environment and to meet Third Offset requirements, it is important for the U.S. Air Force Logistics Community to use lessons-learned in its own IT-enabled supply chain transformation history as well as industry's history to extract best practices and lessons-learned to effectively harness the power of advanced information technologies. The following is a brief summary of IT-related supply chain initiatives that have been observed within the past fifteen years in the U.S. Air Force and Industry.

IT-related U.S. Air Force Supply Chain Initiatives

In 2001, eLog21 was created to be an initiative targeted, "at business process redesign, performance metrics, training, systems, supply chain management, change management, maintenance, and more" (eLog21, 2017). eLog21 represented the Air Force's commitment to boldly change current logistics processes to better support the warfighter; it was designed with the mission of developing and implementing transformational concepts, processes, systems, and policies to deliver dependable, effective, and efficient Agile Combat Support (ACS) to the 21st century expeditionary aerospace force (Transformation Planning Guidance, 2003).

Looking at instructions for the future, the Air Force has published its *Third Offset Strategy*. An 'offset strategy' is defined as, "part of a long-term competitive strategy; a peacetime competition between rival defense establishments that aims to generate and sustain strategic advantage," and, "aims to bolster and extend U.S. conventional deterrence against great powers able to produce or acquire technologically advanced weapons systems" (Lange, 2016). The document is called the Third Offset because it is modeled on two previous offsets. The First Offset was the move to a nuclear-based deterrence strategy during the Korean War. The Second Offset was the development of stealth, precision guided munitions, and other current technologies in the late stages of the Cold War.

The Third Offset's deterrence plan is the Department of Defense's, "attempt to offset shrinking U.S. military force structure and declining technological superiority in an era of great power competition" (Eaglen, 2016). Within this strategy, Deputy Defense Secretary Robert Work called for incorporating more automation into warfighting technology (Work, 2015). Based on this request, the *Third Offset Strategy* stands on five main pillars: autonomous learning systems, human-machine collaboration, assisted human operations, manned-unmanned combat teaming, and cyber electronic warfare.

Autonomous learning systems have the ability to acquire knowledge without being explicitly programmed to. Experts at IBM explained during a panel discussion, "machine learning does this by consuming greater amounts of data, supporting greater variability and complexity, and being more forgiving of changing parameters or data points. Output generated through this process can be deployed seamlessly across multiple different platforms, like cloud computing and on-premises applications, analytics systems, embedded systems and edge networks" (IIoT Summit, 2016).

The second pillar, human-machine collaboration, also embraces the idea of a technology-based operating environment. Participants at a 2012 workshop organized by the Board on Global Science and Technology of the National Research Council suggested several definitions of human-machine collaboration including, "machines and humans combining each other's strengths and filling in for their weaknesses and empowering each other's capabilities, machines being partners rather than tools for humans, and technology that amplifies and extends human abilities to know, perceive, and collaborate" (Brake, 2015).

Human machine combat teaming embraces the last three pillars, requiring full integration of humans and drones in combat – the Department of Defense defines it as, "[working] with the unmanned systems to perform operations" (Pellerin, 2015). Likewise, assisted human operations requires embracing and integrating technology into the mission by involving technologies such as, "wearable electronics, combat apps, heads-up displays and even exoskeletons that can help warfighters in all possible contingencies" (U.S. Army, 2016).

IT-related Industry Supply Chain Initiatives

Since the Technology Revolution, companies have begun to see the globalization of supply chains. In the past fifteen years, "the focus on globalization accented the need for logistics strategies to deal with complex networks including multiple entities spanning multiple countries with diverse control" (The Evolution of SCL, 2017). According to a McKinsey & Company article titled *Manufacturing the Future: The Next Era of Global Growth and Innovation*, by the year 2020, 80% of the goods in the world will be manufactured in a country different from where they are located (Dobbs et al., 2012). The growth of supply chain networks, characters, and levels of interconnectedness makes for new challenges within the future of the Logistics Community. Researchers address this issue in the article *Future-Focused Supply Chains: Supply Chain Strategies Shaped by the Future* saying (Singh, 2017):

> "The increasing unpredictability and complexity of events is particularly problematic for supply chains, which must interact closely with external as well as internal entities in order to perform effectively. Further, as supply chains have become critical to competitiveness, they are driven to become rigid in order to meet efficiency and reliability goals. Unfortunately, these goals are very difficult to reconcile with the growing need for flexibility. This conflict is at the heart of future supply chain challenges."

Forbes published the article *Five Supply Chain Predictions for 2016*, proposing, "the use of predictive analytics, planning tools and machine-learning will skyrocket" (Martyn, 2015). Similarly, Adam Robinson touched upon three key trends related to this research in his January article, *2016 Supply Chain Trends*:

Trend #1: Supply Chains will look to Go Digital
Trend #2: Augmented Reality
Trend #3: Artificial Intelligence on Steroids.

Top industries agree that they are seeing exactly this within organizations. In a 2016 Industrial Internet of Things (IIoT) Summit, a representative from the global leader in engineering simulation software stated, "if you look at [industry], their aircrafts are operating in the field and they're taking that sensor data and then predicting the life of the aircraft engine and driving down the overall maintenance cost" (IIoT Summit, 2016).

Putting initiatives like the Third Offset into place supports the idea that the Department of Defense is following suit with industry experts' predictions. Considering past experiences with difficulties in technological implementation within the U.S. Air Force Logistics Community, it is paramount consider history and understand what factors have been noted as critical to success in order to experience the full benefits of new technologies and identify which are applicable to this issue.

Motivation

The U.S. Air Force has been forced to operate in an environment with constrained resources that continue to become increasingly scarce. Consistent with the revised caps in the Bipartisan Budget Act of 2013, fiscal year (FY) 2014 enacted appropriations reduced Department of Defense funding by $31 billion compared with the President's Budget request. With the addition of projected sequestration-level cuts for FY 2016 through 2021, reductions to planned defense spending for the ten-year period from FY 2012 to 2021 will exceed $1 trillion (Estimated Impacts of Sequestration, 2014).

In combination with the overall decrease in the DoD's budget, the number of U.S. Air Force aircraft and workforce size is decreasing as well. It was announced in 2014 that the Air Force intended to cut approximately 500 planes from its inventory throughout the following five years due to budget constraints (Harper, 2017). "In addition to fleet divestment, we made the tough choice to reduce a number of tactical fighters, command and control, electronic attack and intra-theater airlift assets so we could rebalance the Air Force at a size that can be supported by expected funding levels," Air Force Chief of Staff General Mark A. Welsh III stated in a news release (Cenciotti, 2017).

Meanwhile, the need for the U.S. Air Force capabilities has grown despite the shrinking workforce size. "Demand for our services is way, way up," said Secretary of the Air Force, Ms Deborah James, in a January 2015 State of the Air Force press briefing. She added, "we are meeting those demands today with the smallest Air Force in our history. And when you couple that smaller force against the backdrop of austere budgets, and with the huge demand, what we have is we have a total force that is under significant strain" (Sirota, 2017).

To meet these new requirements, the U.S. Air Force has strived to increase levels of efficiency in budget and resource utilization. “The FY15 [budget proposal] request favors a smaller and more capable force,” Defense Secretary Chuck Hagel said (Harper, 2014). In addition to budget adjustments, the U.S. Air Force workforce has taken steps to down-size and cross-train manpower. “The increasing focus on strategic cost management has led many senior managers to turn their attention to indirect spend to realize cost savings, reductions, or avoidances” (Johnson et al., 2011). Additionally, other countries have already begun to follow this IT-based trend (see Appendix I).

Problem Statement

As noted in the initial review of the subject, the U.S. Air Force has attempted to implement numerous IT-related supply chain initiatives with limited success in finding a holistic, trustworthy solution. Adversaries’ access to new technology is growing and “the gap between the economic performance of nations and that of companies is growing wider every month, made worse by offshoring and advances in technology” (Harvard Business Review, 2006). Additionally, the U.S. Air Force’s decrease in workforce and budget allocation paired with the increase in adversaries’ capabilities and growing demand for its services leaves a gap between where it is and where it needs to be to sustain competitive operational ability. In order to remain competitive in the evolving global warfighting environment, it is important for the U.S. Air Force Logistics Community to use lessons-learned in its own IT-enabled supply chain transformation history, as well as industry’s history to extract critical factors for implementation to effectively harness the power of advanced information technologies.

Purpose Statement

Pairing the pressing need for efficiency with the need to remain competitive, it is paramount for the U.S. Air Force Logistics Community to develop a strategy regarding the critical factors to evaluate when implementing new IT-based initiatives to obtain the most effective results. The purpose of this research is to examine U.S. Air Force and industry supply chain information technology initiatives to extract best practices and lessons learned from the last 15 years to identify relevant critical success factors for the successful adoption of new supply chain technologies. Based on the findings from a preliminary literature review and semi-structured interviews with industry experts, four propositions have been developed as critical success factors for the U.S. Air Force Logistics Community to consider when evaluating potential supply chain-based information technology initiatives. The four critical factors proposed in this research include policy, workforce education, investment, and industry partner collaboration.

Research Questions

RQ1.) How is technology transforming the supply chain?

RQ2.) What factors have been identified as critical for successful information technology implementation?

RQ3.) What factors should the U.S. Air Force Logistics Community identify as critical in the evaluation of potential supply chain transformation initiatives?

Scope

Due to the innumerable angles at which this topic can be approached, this thesis has been limited to four research focuses on which the propositions made in the conclusion are based. The four selected focuses (policy, workforce education, investment, and industry partner collaboration) were noted both in the review of literature and in interview data collected from panel questions asked at the 2016 IIoT Summit. Additionally, this research looks strictly into information technology related initiatives and evolutions within the U.S. Air Force Logistics Community. No non-IT or non-U.S. Air Force logistics transformations were specifically reviewed.

II. LITERATURE REVIEW

This section answers Research Question #1: *How is technology transforming the supply chain?* via content analysis of structured queries regarding the documented history of IT-enabled supply transformations seen within the U.S. Air Force and industry partners. Key phrases searched for included: "supply chain transformation," "information technology," "U.S. Air Force," and "logistics." Search results were additionally restricted to publish dates from the years 2000 – present. Specific eLog21 initiatives discussed in the following section are limited to the Expeditionary Combat Support System, Purchasing and Supply Chain Management, Logistics Enterprise Architecture, and Condition Based Maintenance Plus. The four initiatives expanded upon were selected due to appropriateness regarding relevance to information technology and the supply chain.

Expeditionary Logistics for the 21st Century

Expeditionary Logistics for the 21st Century (eLog21) was an initiative targeted, "at business process redesign, performance metrics, training, systems, supply chain management, change management, maintenance, and more, with the primary objective of improving logistics operations, eLog21 represented the Air Force's commitment to boldly change current logistics processes to better support the warfighter" (eLog21, 2017). With its first elements beginning in 2001, the campaign was designed with the mission of developing and implementing transformational concepts, processes, systems, and policies to deliver dependable, effective, and efficient Agile Combat Support (ACS) to the 21st century expeditionary aerospace force (DoD Transformation Planning Guidance, 2003). Utilizing IT-enabled tools, Lean and Six Sigma techniques were used to assist the Air Force to ensure premier, agile support for expeditionary operations, implement an integrated logistics enterprise, institutionalize performance-based logistics to ensure today's warfighter readiness, and improve defense capabilities and cost effectiveness through innovative, world-class logistics operations (Joint Concepts for Logistics Vision, 2000).

Lean Practices encompass many techniques that major businesses have been working to adopt in order to remain competitive in an increasingly global market. The focus of the approach is on cost reduction through eliminating nonvalue added activities. Lean Manufacturing's focus is on the systematic elimination of wastes from an organization's operations through a set of synergistic work practices to produce products and services at the rate of demand. Multiple manufacturing practices are commonly associated with Lean Production (see Figure 1) (Shah and Ward, 2002).

Lean practice	Sources															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Bottleneck removal (production smoothing)																
Cellular manufacturing									*			*	*	*	*	*
Competitive benchmarking																
Continuous improvement programs		*				*	*	*	*		*	*	*	*	*	*
Cross-functional work force	*		*		*	*			*		*	*	*	*	*	*
Cycle time reductions									*			*	*		*	*
Focused factory production									*		*	*	*	*	*	*
JIT/continuous flow production	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Lot size reductions	*	*		*	*	*	*	*	*	*	*	*	*		*	*
Maintenance optimization																
New process equipment/technologies									*			*			*	
Planning and scheduling strategies																
Preventive maintenance			*			*		*	*	*	*	*	*	*	*	*
Process capability measurements									*			*	*	*	*	
Pull system/kanban	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Quality management programs		*														
Quick changeover techniques	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Reengineered production process																
Safety improvement programs									*			*			*	
Self-directed work teams		*					*	*	*	*	*	*	*	*	*	
Total quality management		*				*	*	*	*		*	*	*	*	*	*

(1) Sugimori et al. (1977); Monden (1981); Pegels (1984); (2) Wantuck (1983); (3) Lee and Ebrahimpour (1984); (4) Suzaki (1985); (5) Finch and Cox (1986); (6) Voss and Robinson (1987); (7) Hay (1988); (8) Bicheno (1989); (9) Chan et al. (1990); (10) Piper and McLachlin (1990); (11) White (1993); (12) Shingo Prize Guidelines (1996); (13) Sakakibara et al. (1997); (14) Koufteros et al. (1998); (15) Flynn et al. (1999); (16) White et al. (1999).

Figure 1. Lean Manufacturing Practices (Shah and Ward, 2002)

Six Sigma is defined as, “a business strategy that focuses on improving customer requirements understanding, business systems, productivity, and financial performance” (Anbari and Kwak, 2006). Six Sigma is a way to express quality goals, measuring process failures where process variability is ±6 standard deviations from the mean (see Figure 2) (Choo et al., 2003). The fundamental idea behind the Six Sigma philosophy is to continuously reduce variation in processes and aim at the elimination of defects of failures from every product, service, and transactional process (Antony and Banueles, 2002).

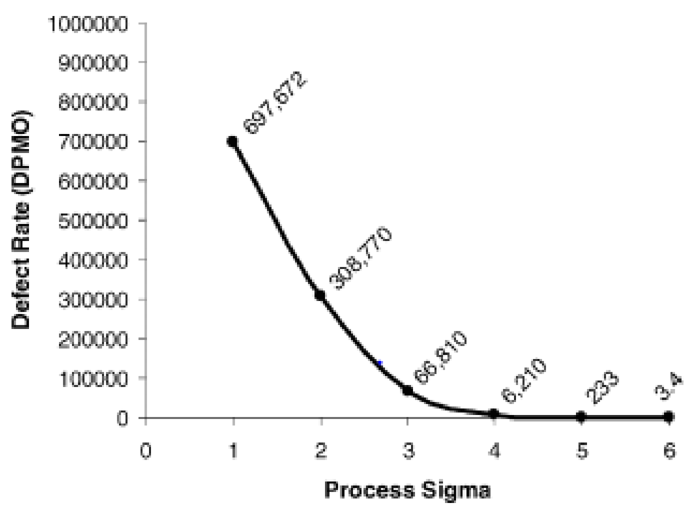

Figure 2. Sample Defect Rate at Six Sigma Levels (Choo et al., 2003)

Being a logistics-focused transformation, eLog21 was a set of complementary initiatives for all logistic areas used to enforce Air Force Smart Operations for the 21st Century (AFSO21) objectives. Specifically, eLog21 was implemented to meet the following criteria per the 2001 General Accounting Office (GAO) Report:

Optimization of warfighter support, improvement of strategic mobility to meet operational requirements, utilization of customer wait time as a cascading metric, full implementation of total asset visibility, reengineering of processes and systems applicable to communications and situational awareness, and achieve best-value logistics while meeting existing requirements at reduced operating costs.

Seven specific, measurable goals of eLog21 included an increase in equipment availability of 20%, a reduction of operating and support (O&S) costs of 10%, a 20% reduction in the mobility footprint, a 50% reduction in cycle times, a 95% improvement of Time Definite Deliveries, an improvement in O&S cost estimation to a 90% confidence level, and a 10% improvement in workforce satisfaction (Subcommittee on Investigations, 2014). eLog21 was considered an umbrella effort that overarched over twenty additional, strategic initiatives utilizing IT capabilities to implement plans and achieve the established goals.

Expeditionary Combat Support System

Expeditionary Combat Support System (ECSS) was the eLog21 initiative designed to target the IT modernization component of the overall logistics transformation efforts and provided the vehicle to drive the transformation of the logistics enterprise. Beginning in 2004, the Air Force worked to implement an Enterprise Resource Planning (ERP) system that aimed to merge base-level and wholesale logistics systems and deliver hard net-savings for the Air Force (Subcommittee on Investigations, 2014). The ERP system was a pre-packaged software meant to replace old, disparate computer systems with a single, unified software program comprised of multiple modules. The ECSS ERP modules encompassed finance, budget, facilities management, bill of materials, repair and maintenance, distribution, quality control, materials management, decision support, product life cycle management (PLCM), advanced planning and scheduling (APS), personnel, and customer relationship management (CRM) departments to create a collective center for data.

DoD policies and the U.S. Air Force economy demanded cost reduction while maintaining, if not requiring an increase in, levels of equipment availability. U.S. Air Force senior leaders realized that the level of cost savings and efficiency necessary to remain competitive could not be reached with the existing tools and processes. A large opportunity for cost savings was identified through forming a single, all-encompassing database. The Air Force therefore implemented ECSS to dramatically lower and amalgamate the then 400+ legacy IT systems; 173 of these systems supported a majority of the Air Force Logistics functionality (eLog21 Fact Sheet - ECSS, 2017). ECSS specifically targeted two of the seven aforementioned eLog21 measurable objectives: a 20% increase in equipment availability and a reduction of O&S costs by 10% (Subcommittee on Investigations, 2014). Efforts of this initiative were meant to reduce the overall O&S cost of IT through the elimination of redundant and obsolete systems. At the same time, ECSS aimed to increase the overall usability and functionality of existing, pertinent data by creating a single, unified database.

ECSS was initially intended to be a combination of three COTS products, ORACLE R12 eBusiness suite, IFS and Click; however, approximately a year into the blueprinting process, it became apparent that the combination of products was not as integrated as represented by the vendors and would not meet the needs of the Air Force without a significant change in direction (U.S. Comptroller General, 2007). To address the issue, the ECSS program was restructured and the IFS and Click product components of the software suite were abandoned (Bailey et al., 2011). Eight years after continued implementation efforts, the DoD issued a stop work order ECSS and deemed it, "an opportunity to harvest technologies and lessons learned" (Charette, 2012).

Purchasing and Supply Chain Management

Purchasing and Supply Chain Management (PSCM) was an eLog21 initiative directed towards improving and integrating the Air Force Materiel Command's (AFMC) purchasing and supply processes. The end result of PSCM was to create a single, end-to-end supply chain process that spanned the Air Force's entire supply system (PCSM Fact Sheet 4, 2004). In the year 2002, the PSCM transformation began working to increase available parts to the warfighter, reduce costs of doing business, and to improve product quality and delivery enterprise-wide (Arkes and Chenoweth, 2008).

PSCM was initiated by Air Force Senior Leaders to rapidly reduce costs, improve performance, and address five additional concerns (PCSM Fact Sheet 4, 2017):

1. Current sustainment processes did not meet the needs of the American Expeditionary Force (AEF)
2. Weapons System sustainment costs were impeding modernization
3. Increased competition from external sources
4. Increased pressure for cost reductions and improve availability of weapons systems
5. Growing loss of Intellectual Capital

The AFMC PSCM Integrated Product Team (IPT) planned to develop seamless and transparent PSCM processes that would improve product quality, delivery and reduce purchasing costs (PCSM Fact Sheet 4, 2017). To achieve these goals, the IPT planned to collaborate with customers and suppliers, build seamless end-to-end processes, design in process flexibility and agility, integrate purchasing and supply functions, and develop PSCM as a core capability.

Logistics Enterprise Architecture

Logistics Enterprise Architecture (LogEA) was a strategic road map which shaped the transformation and worked in accordance with eLog21 to set the foundation for the Air Force logistics transformation of the 21st century. LogEA provided an authoritative source to define both operational and systems approaches to Air Force logistics as well as defined and aligned the organizational vision, mission, goals, objectives, and processes with information technology initiatives (Air Force Studies Board, 2011). “It aimed to ensure that life-cycle logistics were addressed at every step from the lab, to the requirements, to the design and testing, to the manufacturing and delivery process through exploring innovative technologies and incorporates a number of product support initiatives” (eLog21 Fact Sheet - PSCM, 2017).

Due to the size and complexity of the Air Force’s supply chain, significant opportunities to improve logistics performance and cost exist; however, “processes, organizations, and systems limited the ability to realize dramatic improvement” (LogEA Fact Sheet, 2017). Many siloed, individual logistical initiatives have taken place, but optimization of a single center does not guarantee total force optimization and can often lead to an overall decrease in supply chain performance metrics of the rest of the enterprise. There are many disparate, ongoing initiatives within the logistics community that seek to improve logistics performance. While initiatives may be moving towards sound goals, they are not necessarily moving toward common goals. There is not a common awareness or understanding of how these initiatives must integrate in a coordinated fashion to meet Air Force corporate goals. Further, multiple architectures are being developed at the OSD level, Air Force level, Command Level, and Air Staff level that require Logistics involvement and compliance. The goals of this initiative included a 20% increase in equipment availability; reduce annual O&S cost by 10% ($3.5B) NLT FY11 (LogEA Fact Sheet, 2017).

Condition Based Maintenance Plus

Condition Based Maintenance Plus (CBM+) had a broad scope, being, “built upon the concept of Condition Based Maintenance, but enhanced by reliability analysis” (CBM+, 2017). The Air Force defines Condition Based Maintenance (CBM) as, “a set of maintenance processes and capabilities derived from real-time assessment of weapon system condition obtained from embedded sensors and/or external test and measurements using portable equipment” (CBM+, 2017). The goal of CBM is to perform maintenance only upon evidence of need. The Air Force slightly modified the CBM+ definition to clearly communicate that CBM+ is integrated throughout the life of the Air Force weapon systems.

CBM+ expands upon the basic concepts of CBM by encompassing other technologies, processes, and procedures that enable improved maintenance and logistics practices. Future and existing technologies will be used to processes these capabilities using Full Spectrum Dominance. “Full Spectrum Dominance – attaining that goal requires the steady infusion of new technology. Of greater importance is the development of doctrine, organizations, training and education, leaders and people that effectively take advantage of the technology” (Joint Chiefs of Staff, 2000).

Industry

Similar to the Air Force, a vast amount of research has been, and is currently being conducted in industry to study information technology and its impact on the supply chain. “Looking backward, the trends that dominated supply chain management are easy to spot. “The 1980s were all about the demands of just-in-time. In the ’90s it was outsourcing and in the ’00s it’s been the emergence of the Internet — which especially shaped procurement practices” (Fine and Simchi, 2010).

Industry is embracing its own version of the Third Offset and calls it the Third Wave of IT-driven Competition. “Professors from Harvard University have stated that the Internet of Things (IoT) and Industrial Internet with smart, connected products can be considered a Third Wave of IT-driven Competition” (Elsinga et al., 2015). Industry’s First Wave of IT-driven Competition was seen in industry in the 1960s and 1970s with, “automated individual activities in the value chain, from order processing and bill paying to computer-aided design and manufacturing resource planning” (Porter and Heppelmann, 2015). Michael Porter and James Heppelmann in their 2014 Harvard Business Review article, *How Smart, Connected Products Are Transforming Competition,* state that, as a result of this new technology, “the productivity of activities dramatically increased, in part because huge amounts of new data could be captured and analyzed in each activity. This led to the standardization of processes across companies—and raised a dilemma for companies about how to capture IT’s operational benefits while maintaining distinctive strategies.”

At the Cognitive Infocommunications 2015 IEEE International Conference, it was stated that, “the second wave [of IT-driven Competition], occurring during the 1980s and 1990s, was the rise of the Internet, which enabled coordination and integration across individual activities even for outside suppliers and customers" (Elsinga et al., 2015). The Third Wave of IT-driven Competition, includes: embedded sensors, processors, software, and connectivity in products, coupled with a product cloud in which product data is stored and analyzed and some applications are run, are driving dramatic improvements in product functionality and performance. Massive amounts of new product-usage data enable many of those improvements (Porter and Heppelmann, 2015).

A large amount of literature cites the importance of IT on an entity's supply chain. "Companies have sought to exploit network effects since W. Brian Arthur dubbed them the competitive linchpin for information-age business. Many have used technology to tie together critical masses of customers and the most or best suppliers and so have gained an edge, but now enough companies derive competitive advantage from their networks that they are coming up against one another" (Harvard Business Review, 2006). Additional research cites that, "a positive, significant relationship was found between supply chain integration and operational performance in all the models used" (Kim, 2013). The report *Developing a Reverse Logistics Competency: The Influence of Collaboration and Information Technology* agrees, stating, "support is found for the positive moderating influence of an IT competency on the relationship between collaboration and a reverse logistics competency. Additional benefits for logistics performance are also realized" (Morgan et al., 2016).

It is clear where competitive trends are heading. Researchers report, "as traditional supply chains are increasingly becoming intelligent with more objects embedded with sensors and better communication, intelligent decision making and automation capabilities, the new smart supply chain presents unprecedented opportunities for achieving cost reduction and enhancing efficiency improvement" (Jin et al., 2016). "The powerful new data available to companies, together with new configurations and capabilities of smart, connected products, is restructuring the traditional functions of business—sometimes radically. This transformation started with product development but is playing out across the value chain [and] smart, connected products will ultimately move logistics to a whole new generation" (Porter and Heppelmann, 2015).

Though studies have noted the importance of these technologies, adopting them has proven to be a challenge for most business environments. "Adopters of supply chain technologies (SCT) experience significant and numerous unmet expectations associated with SCT implementation" (Knemeyer et al., 2015). As noted previously, this barrier has been seen directly in past U.S. Air Force supply chain IT-based initiatives history as well. "Smart, connected products raise a new set of strategic choices related to how value is created and captured, how the prodigious amount of new (and sensitive) data they generate is utilized and managed, how relationships with traditional business partners such as channels are redefined, and what role companies should play as industry boundaries are expanded" (Porter and Heppelmann, 2015).

Fortunately, the topic of implementing technologies to harness the power of data has been thoroughly studied. An analysis of documented critical success factors and lessons learned can help better understand how experts have identified to successfully integrate supply chain-centric information technologies into an environment. As part of this research, a summary of these critical factors is addressed in the Results and Analysis section of this document.

Theoretical Development

When researching the implementation of IT-based systems in an environment, multiple theories have been applied such as Expectancy Value Theory, Grounded Theory, Cultural Dimensions Theory, and more (see Appendix II). The Diffusion of Innovation Theory was most commonly used in regard to the successful implementation of information technologies, and was discussed first in 1903 by the Gabriel Tarde who plotted the original S-shaped diffusion curve (Toews, 2003). Ryan and Gross later introduced the adopter categories that were later used in the current theory popularized by Everett Rogers (see Figure 3). “In simple terms, the diffusion of innovation refers to the process that occurs as people adopt a new idea, product, practice, philosophy, and so on” (Kaminski, 2011). Within the Diffusion of Innovation Theory, there are five stages of adoption: awareness, interest, evaluation, trial, and adoption. The adoption decision separates initiation of an idea from its implementation and there are five factors that affect innovation adoption: innovation factors, individual factors, task factors, environmental factors, and organizational factors (Rogers, 1995).

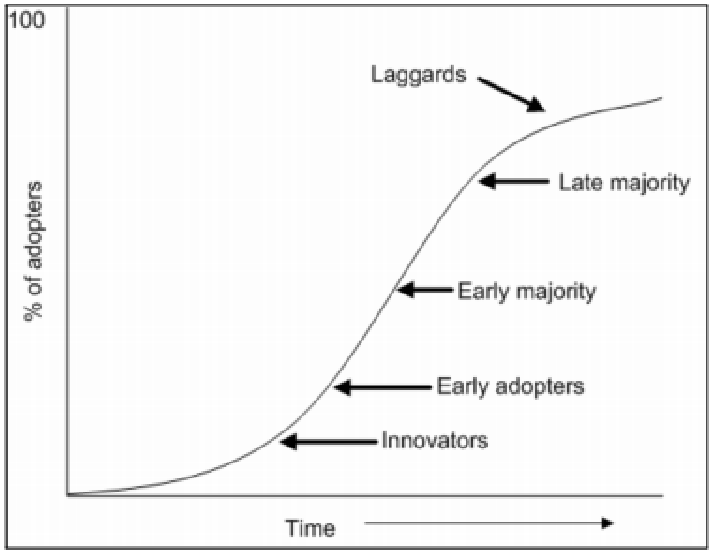

Figure 3. Everette Rogers Rate of Adoption Curve (Rogers, 1995)

Based on the categorization of the adopter, decision-makers can be broken down in the following way (Rogers, 1995):

Characteristics of the Innovators:

(1) venturesome, desire for the rash, the daring, and the risky

(2) control of substantial financial resources to absorb possible loss from an unprofitable innovation

(3) the ability to understand and apply complex technical knowledge

(4) the ability to cope with a high degree of uncertainty about an innovation

Characteristics of the Early Adopters:

(1) integrated part of the local social system

(2) greatest degree of opinion leadership in most systems

(3) serve as role model for other members or society

(4) respected by peers

(5) successful.

Characteristics of the Early Majority:

(1) interact frequently with peers

(2) seldom hold positions of opinion leadership

(3) one-third of the members of a system, making the early majority the largest category

(4) deliberate before adopting a new idea

Characteristics of the Late Majority:

(1) one-third of the members of a system

(2) pressure from peers

(3) economic necessity

(4) skeptical

(5) cautious

Characteristics of the Laggards:

(1) possess no opinion leadership

(2) isolates

(3) point of reference in the past

(4) suspicious of innovations

(5) innovation-decision process is lengthy

(6) resources are limited

Based on "best-fit," the Diffusion of Innovation Theory was selected to help better understand the issue identified in the Problem Statement. When looking at the adoption of IT-based supply chain solutions through the theoretical lens of the Diffusion of Innovation Theory, the U.S. Air Force Logistics Community can be seen as part of the late majority. This categorization is supported through the skepticism and caution the U.S. Air Force Logistics Community expresses, as well as the fact that the motivation is driven by economic need and peer pressure.

Because the U.S. Air Force Logistics Community falls into the late majority category regarding IT-enabled integration, theory states that it is important to understand the impact of steps in the aforementioned five-step process of diffusion (awareness, interest, evaluation, trial, and adoption). To successfully diffuse technology within the late majority sector, high levels of knowledge and surety are required (Toews, 2003). This research seeks to fill the U.S. Air Force Logistics Community's knowledge gap regarding the diffusion of information technologies and inform readers on four factors deemed as critical to successfully implement IT-related (policy, workforce education, investment, and industry collaboration).

III. METHODOLOGY

Data Collection Method

Qualitative research methods will be used to determine answers to Research Questions #2 and #3 based on the recommendation to use qualitative research methods when developing models and theories to explain current phenomena (Coghlan and Coughlin, 2002). Via semi-structured interviews, data will be collected at the Air Force Institute of Technology's (AFIT) Center for Operational Analysis (COA) 2016 Industrial Internet of Things (IIoT) Summit. The IIoT Summit will be an open forum designed to fulfill very specific objectives: to discuss how to leverage advancements in IT to our advantage and gain insight on how the Air Force should begin to adopt new technologies.

Through coordinating the Summit, first-hand knowledge will be obtained from U.S. Air Force senior leaders and top industry partner executives regarding what supply chain transformations they have experienced, and how they are preparing for future IT-related supply chain changes. The data collected will come from two panels consisting of a total of eleven subject matter experts (SME) in the fields of logistics and IT with backgrounds in both Air Force and industry. Each SME will be asked two questions at the 2016 IIoT Summit. Answers will be transcribed, analyzed, and summarized.

In addition to the Summit Panels, data will also be collected using structured queries within industry and Air Force databases of published scholarly articles containing the key phrases: "critical success factors," "information technology," and "successful implementation." Most frequently discussed factors will be noted and systematically compared with the results from the IIoT Summit Panels via variable oriented cross-comparison analysis techniques. Commonalities will be identified through content analysis and used to formulate four proposed critical success factors as a suggested framework for the U.S. Air Force Logistics Community to consider when evaluating potential supply chain-based information technology initiatives.

Interviewee Sampling Strategy

Specific SMEs that will serve on the Panel have been selected from current COA partners based on levels of professional experience within the areas of information technology, supply chain, and U.S. Air Force. Panel Members have an average of 25.7 years of experience in one or more of the aforementioned areas; additional details can be found in Figure 4. Selected interviewees for the IIoT Summit Panel include:

Scott Dewicki, Enterprise Supply Chain Practice Lead, Gartner

Chuck Evanhoe, President of Evanhoe & Associates, Inc.; Chairman of IoT10, the U.S. Technical Committee for ISO/IEC JTC1/WG10—IoT Standards Working Group

Steven Foote, Technical Director, Software Engineering Technical Center, MITRE

Sam Gordy, General Manager, U.S. Federal and Government Industries, IBM

Walt Hearn, Director, Ansys

Scott Jenkins, Vice President, North American Sales and Marketing, Yaskawa

Dr Jimmy Kenyon, Senior Director, Advanced Programs and Technology, Pratt & Whitney

Dr Margaret Loper, Chief Scientist and Chief Technologist, Center for the Development and Application of Internet of Things Technologies (CDAIT), Georgia Tech Research Institute

Dr Bob Mills, Director, Center for Cyberspace Research, AFIT

Renee Pasman, Director, ADP Mission System Roadmaps, Lockheed Martin

Mark Valentine, Director, U.S. Air Force Strategic Programs, Microsoft

Figure 4. Years of Professional Experience – IIoT Summit Panel Members

Panel Member Interviews

Based on area of expertise, Panel Members will be separated into two different panels strategically designed to address two particular issues and questions. Interviewees will be given their questions in advance of the Summit and asked to prepare a five-minute response to be delivered at the forum. Panel #1 will be designed for U.S. Air Force industry and research partners to provide a solid understanding of what is happening regarding the increasing availability of data and connectedness of humans, devices, machines, and enterprises. The specific questions and topics to be addressed are as follows:

"What is IIoT: Past, Present, and Future?"

a. How are technology-enabled, data-intensive process structures challenging business norms?

--consider implications to infrastructure investment, manufacturing processes, workforce development, supplier relationships, strategic partnerships, and/or joint ventures.

b. What measures are being taken to prepare for inclusion of advanced data-intensive automation and robotics across ‘connected’ enterprises?

--consider requirements associated with integrating the following capabilities:

1. Assisted Human Operations

2. Autonomous Learning Systems

3. Human-machine Collaboration

4. Human-machine Combat Teaming

5. Network-enabled, Semi-autonomous Technology

Panel #2 will be designed to take the information from the first panel and re-focus it to understand the impact of these technologies across the DoD. SMEs in this aspect will have a vast knowledge of the DoD’s current technologies, policies, and capabilities, with specializations in the Air Force environment. The questions these Panel Members will be requested to target include the following:

Applying IIoT: Realities and Risks in the DoD Domain

a. What are the most significant risks associated with investing in the application and use of advanced technologies in IIoT data-driven domains?

--consider:

1. Effects of Technology Advancement

2. Technology Antiquation

3. Cyber Security

4. Cloud-Based Technology

5. Workforce Skilling

b. What ‘lessons learned’ have been observed to date and what future problem sets should be considered now in preparation for tomorrow’s IIoT resource investments?

Data Analysis Method

Selected unit of analysis for IIoT Summit Panel Member interviews will be at the individual level, allowing for the comparison of a common phenomenon (Bird, 2006). Results will be systematically compared to data from existing literature regarding critical success factors for IT implementation through an analysis of variable oriented cross-comparison methodology. Based on the content analysis, topics deemed as critical success factors by both sources will be used to determine four proposed critical success factors for the U.S. Air Force Logistics Community to consider when evaluating potential supply chain-based information technology initiatives. The four propositions will then be researched to understand what the U.S. Air Force and DoD are currently doing regarding that selected aspect.

IV. RESULTS AND ANALYSIS

IIoT Summit Notable Results

When interviewing Industry Partner Executives and U.S. Air Force Senior Leaders at the 2016 IIoT Summit, a common trend discussed was the need to think about multi-domain solutions, strategic agility, and the global world. Another common trend discussed was regarding the need for a structured but flexible plan to move forward without using monolithic language. A participant stated, “as I talk to public sector organizations, the Air Force, DoD at large, I notice that most of these [factors that lead to unsuccessful implementation] we’re talking about aren’t technology problems. […] They’re mostly cultural problems, and our culture drives policies which allow people to say no.” Workforce competency also was commonly mentioned with representatives asking, “will the availability of people and human capital really constrain or throttle our ability to advance from a manufacturing standpoint?” (IIoT Summit, 2016). Specific noteworthy remarks are identified below. Participant names have been excluded for privacy purposes.

Participant A

Participant A felt data standards were the root of what was important in preparation for agility and successful adoption of new technologies. “It’s all about the data, and that’s been my mantra for years.” To achieve the level of desired outcomes, the Participant urged that it is important for data standards to be correct, standardized across entities, and interconnected. “China is heavily focused on the standards activities. In fact, it’s part of the Chinese five-year plan to be at the head of IoT. They’re investing over $600 billion in U.S. dollars in IoT through 2020” (IIoT Summit, 2016).

Participant B

Participant B referred to DoD changes during the World War II era, stating, “my ultimate goal is to let you know the [IT] transformation is going to happen and you should not be afraid of it. You should not be afraid because you’ve done it before.” The Participant stated that technology is moving from a time where data could give explanations of occurrences in retrospect, to an environment with predictive analytics that will give prescriptive analytics that will not only tell users what will happen and when, but also why it will happen. Another trend the Participant has observed is the evolution of advanced visualization and the ability to take data and present it in a way that is user-friendly to allow for intelligent actions to be taken in situations.

The Participant warned of the major mistakes he had seen in past endeavors to adopt this technology: “we see some companies focusing on the wrong things, so incorrect focus. What I mean by that is they tend to focus on the things themselves instead of the insight and the action piece.” It’s this incorrect focus that Participant B attributes the lack of success to in companies that fail to begin with the right focus (IIoT Summit, 2016).

Participant C

Participant C stated the importance of IT, citing Gartner’s 2016 Top 25 Global Supply Chains publishing that found three key themes appearing in these top companies; all three involving elements of IT and digital business. Another common key to success noted in the publishing was partner collaboration and information sharing. Overall, the key theme of Participant C’s discussion was harnessing big data and business intelligence to create prescriptive outcomes. The Participant ended by warning of security issues companies are on the lookout for quoting, “we also see that within the next [...] three to four years, most of our smart devices are going to be hackable, and we see that already. We see across the board where there are large intrusions but not only are they going to be hackable, they’re going to be the very weapons used to take down entire organizations, ecosystems, and so forth” (IIoT Summit, 2016)

Participant D

Participant D expressed an observance of increased use of assisted human operations and platforms designed to facilitate and generate new creative IT solutions. The Participant also mentioned the overwhelming transition from cloud computing to fog computing. The term fog computing, introduced by the Cisco Systems, is “a paradigm that extends Cloud computing and services to the edge of the network. Similar to Cloud, Fog provides data, compute, storage, and application services to end-users. The distinguishing Fog characteristics are its proximity to end-users, its dense geographical distribution, and its support for mobility. Services are hosted at the network edge or even end devices such as set-top-boxes or access points.”

Another important factor mentioned by the Participant was the OODA Loop. The OODA Loop is, “a succinct representation of the natural decision cycle seen in every context: war, business, product development, or life,” and stands for Observation, Orientation, Decision, and Action. The Participant’s experience has shown that harnessing and leveraging data can help individuals to “tighten” the preverbal OODA Loop, making for faster, more accurate decision making (IIoT Summit, 2016).

Participant E

Participant E referenced the research other countries have been working on and The Army Science Board study, *The Military Benefits and Risks of the Internet of Things*. "From a research perspective, we believe it really comes down to four different areas and that is to understand, to operate, to defend, and to attack." Participant E went on to explain each of the four components:

> **Understand** – This step requires understanding your ultimate goals and how you can better achieve those goals in this new, data-rich environment.
>
> **Operate** – Considering the fact that adversaries are also researching using these technologies, players need to understand how to operate the new environments.
>
> **Defend** – Defend includes understanding the risks of implementing these technologies in order to be able to create the right safeguards and taking the right security measures before implementing this technology.
>
> **Attack** – The final step is taking this technology and using it to help the warfighters in their missions.

The final topic Participant E addressed was the difference between being a first-mover vs. a fast-mover and patch working existing infrastructure vs. starting from a clean slate. The Participant noted that being a first-mover and starting from a clean slate have great advantages, but are also very high risk. Being a fast-mover is advantageous because, "we can learn from those who are actually deploying quickly, making mistakes, and there's a lot of that going on in the dataspace. Being able to learn from that so that the decisions that we make and that we do if we start from a clean slate and invest in something, that we invest in the right thing the first time" (IIoT Summit, 2016).

Analysis

An in-depth review of noteworthy articles was published in the 2001 Business Process Journal titled, *Critical Factors for Successful Implementation of Enterprise Systems*, conclusions can be found in Appendix III. In 2003 a similar article was published titled *Enterprise Resource Planning: Implementation Procedures and Critical Success Factors*; excerpts defining its nine factors are shown in Figure 5. A variable oriented cross-comparison analysis of commonalities was conducted between this data and that found in the IIoT Summit Panel Member responses. Topics deemed as critical success factors by both sources in the content analysis were used to formulate Appendix IV. Based analysis results, propositions were made regarding the most commonly mentioned factors: policy, workforce education, investment, and industry collaboration.

Clear Understanding of Strategic Goals	*"Enterprise resource planning: Implementation procedures and critical success factors in order to satisfy customers, empower employees,and facilitate suppliers for the next three to five years."*
Commitment by Top Management	*"The implementation project should have an executive management planning committee that is committed to enterprise integration, understands ERP, fully supports the costs, demands payback, and champions the project."*
Project Management	*"A clear definition of project objectives and a clear plan will help the organization avoid the all-too-common ''scope creep'' which can strain the ERP budget, jeopardize project progress, and complicate the implementation"*
Organizational Change Management	*"[ensuring] the existing organizational structure and processes [...] are compatible with the structure, tools, and types of information provided by ERP systems."*
Implementation Team	*"Management should constantly communicate with the team, but should also enable empowered, rapid decision making."*
Data Accuracy	*"Because of the integrated nature of ERP, if someone enters the wrong data, the mistake can have a negative domino effect throughout the entire enterprise."*
Extensive Education and Training	*"Education/training is probably the most widely recognized critical success factor, because user understanding and buy-in is essential. ERP implementation requires a critical mass of knowledge to enable people to solve problems within the framework of the system."*
Focused Performance Measures	*"Measures should indicate how the system is performing [and] must also be designed so as to encourage the desired behaviors by all functions and individuals."*
Multi-site Issues	*"The desired degree of individual site autonomy may be a critical issue which depends on two factors: (1)the degree of process and product consistency across the remote sites, and (2)the need or desire for centralized control over information, system setup, and usage."*

Figure 5. Critical Factors for Successful Implementation (Haft et al., 2003)

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Research Question #1

Research Question #1: *How is technology transforming the supply chain?* is answered in the initial review of the literature. U.S. Air Force publications cite the use of IT to support the transformation initiative eLog21 through SCOR and Six Sigma techniques. Spawning from eLog21 came many additional initiatives which, unfortunately, had limited success and failed to produce desired improvements (e.g. ECSS, PSCM, LogEA, and CBM+). Looking towards the future, the DoD has published its *Third Offset Strategy* posing a new set of challenges for the U.S. Air Force Logistics Community. Likewise, supply chains within industry are seeing the same phenomenon in what experts call the Third Wave of IT-driven Competition. Similar to the *Third Offset Strategy*, the Third Wave of IT-driven Competition is based off of two previous 'waves' and encompasses the IIoT which utilizes data from smart, connected products.

Research Question #2

Research Question #2: *What factors have been identified as critical for successful information technology implementation?* is addressed in the Results and Analysis section. Many factors were deemed as critical to IT implementation success according to SMEs at the 2016 IIoT Summit (e.g. global mindset, industry partner collaboration, accurate input data, etc.). Other additional critical factor data found in structured queries of literature included effective communication, premier implementation team, and software compatibility. Overall, the four criteria noted as critical to success mentioned by both the

2016 IIoT Summit interviewees and literature included policy, workforce education, investment, and collaboration with industry partners.

Research Question #3

Based on the findings from a review of existing literature and semi-structured interviews with subject matter experts, four propositions have been developed as a suggested framework for the U.S. Air Force Logistics Community to consider when evaluating potential supply chain-related information technology initiatives. Though many factors were noted as important in initial data collected, four specific factors were deemed as critical to success in findings from both methods of data collection. This research's proposition for critical success factors for successful adoption of new supply chain technologies into the U.S. Air Force Logistics Community are as follows:

Policy

"An understanding of culture is important to the study of information technologies in that culture at various levels, including national, organizational, and group, can influence the successful implementation and use of information technology" (Leidner, 2006). Within the Department of Defense, there are three decision-making systems within the DoD acquisition process: the requirements process within the Joint Capabilities Integration and Development System (JCIDS), the Planning, Programming, Budgeting and Execution (PPBE) process; and the Defense Acquisition System. The JCIDS is the DoD's process for defining DoD's acquisition requirements, "to ensure the joint warfighter receives the capabilities required to successfully execute the missions assigned to them. [...] The requirements process supports the acquisition process by providing validated capabilities and associated performance criteria to be used as a basis for acquiring the right weapon systems" (Joint Chiefs of Staff, 2015)

It is important to have a strong policy that is simultaneously flexible to adjustments. A representative from the 2016 IIoT Summit stated, "what we've seen is industry and government collaborating in a way that allows for setting a vision, but not have it be so detailed and so specific that you in fact stifle innovation. As the technology matures and as things are applied, that standard [should be] a growing, living document, and, again, it's built on a somewhat of a consensus basis and somewhat of a realistic approach to how you get people to work together" (IIoT Summit, 2016).

Workforce Education

The importance of people when successfully implementing information technology into an environment has been thoroughly noted in both literature and in subject matter expertise. Hsiu-Fen Lin reports that, "information technology deployment capability, operational capability, human resource capability, and knowledge sharing are important antecedents of e-Supply Chain Management (e-SCM) diffusion. In turn, higher levels of e-SCM diffusion lead to greater competitive performance." Lin goes further to state that, "managers should recognize that human resource development activities (recruiting, training, and managing valuable e-SCM personnel) are an important source of e-SCM diffusion." Lin also prompts that managers must, "establish the connection between human resource capabilities and e-SCM diffusion (i.e., "soft-side" e-SCM) such as hiring and retaining skilled e-SCM personnel, training and development for e-SCM personnel, and measuring e-SCM personnel's global mindset over time" (Lin, 2017).

Information Dominance and Chief Information Officer (SAF/CIO A6) Lt Gen William J. Bender recognized the importance of organization and education of the workforce in the February 2017 *Information Dominance Vision* (see Figure 6), reporting that, "in addition to investing in information dominance capabilities, we will recruit and retain Airmen with cyber and data analytics talent through modern accessions, training, and retention methodologies used in the private sector. Through innovative means, we will evaluate and entice workforce talent; create opportunities to incorporate 'non-traditional' talent; and support alternatives for retention of Airmen with mission critical skills" (SAF/CIO A6, 2017).

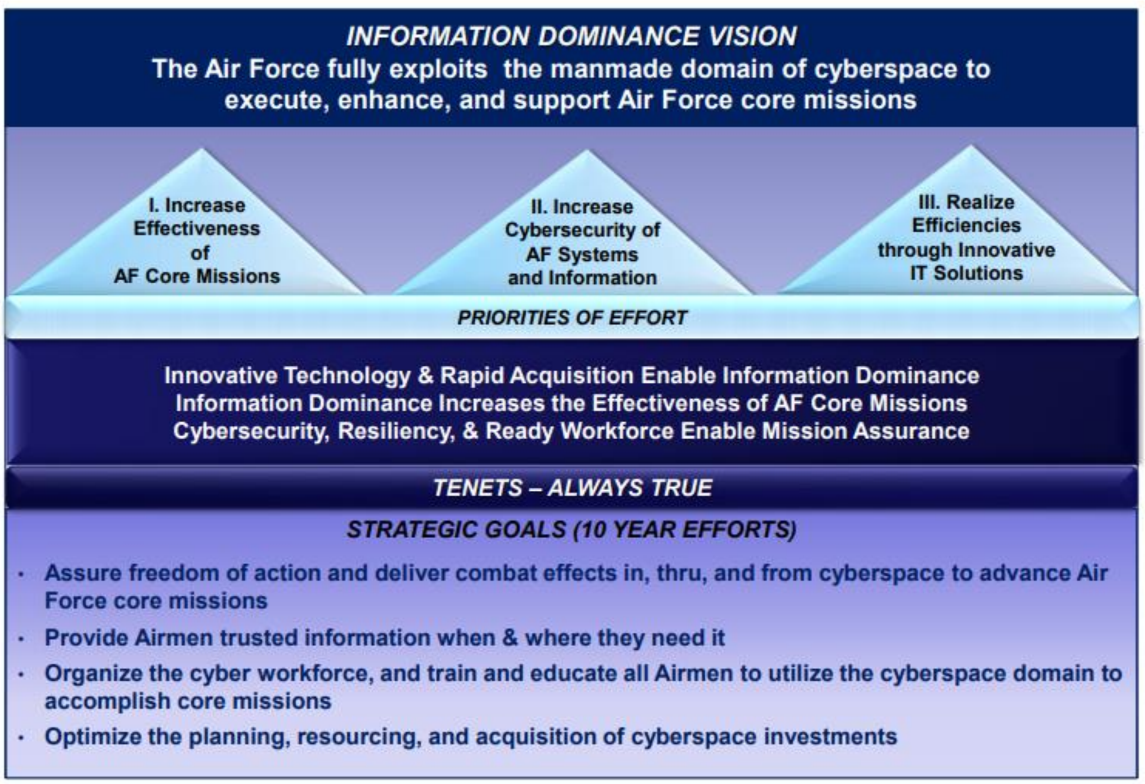

Figure 6. SAF/CIO A6 Information Dominance Vision (SAF/CIO A6, 2017)

"While initial investments in information technology yield alluring gains, performance benefits diminish as social resistors create limiting conditions. The dynamic capability for firms to recognize and respond to the dual and integrative nature of technical and social systems is required for firms to overcome powerful limiting conditions and change resistors through collaborative process design in order to cultivate new value-creation processes" (Fawcett et al., 2017).

Investment

"Information technology purchasing is covering an increasing part of companies' expenditure" (Brun et al., 2013). Likewise, the Insider reported on 7 June 2017, "the Air Force plans to expand the ranks of its digital-domain leadership by adding a new chief data officer (CDO) position, the service's chief information security officer said today" (Karas, 2017). The Business of Federal Technology reported in June 2016, "the Federal Aviation Administration is looking to hire its first chief data officer. In a June 10 job posting, the FAA notes that the new leadership role will require thinking about data both offensively and defensively: The agency wants to use and share its data in new ways, while also minimizing the risk that valuable data might be hacked" (Noble, 2016). Agencies of the United States federal government are adopting the CDO trend as well (see Figure 7).

This investment in CDOs shows a strong effort to foster a new revolution of IT-related supply chain initiatives to embrace the third offset pillars and begin to take steps in the right direction. Investment is also required from an emotional standpoint. In a review of data collected from the IIoT Summit and documents regarding critical success factors for successful IT implementation, support from top management was key.

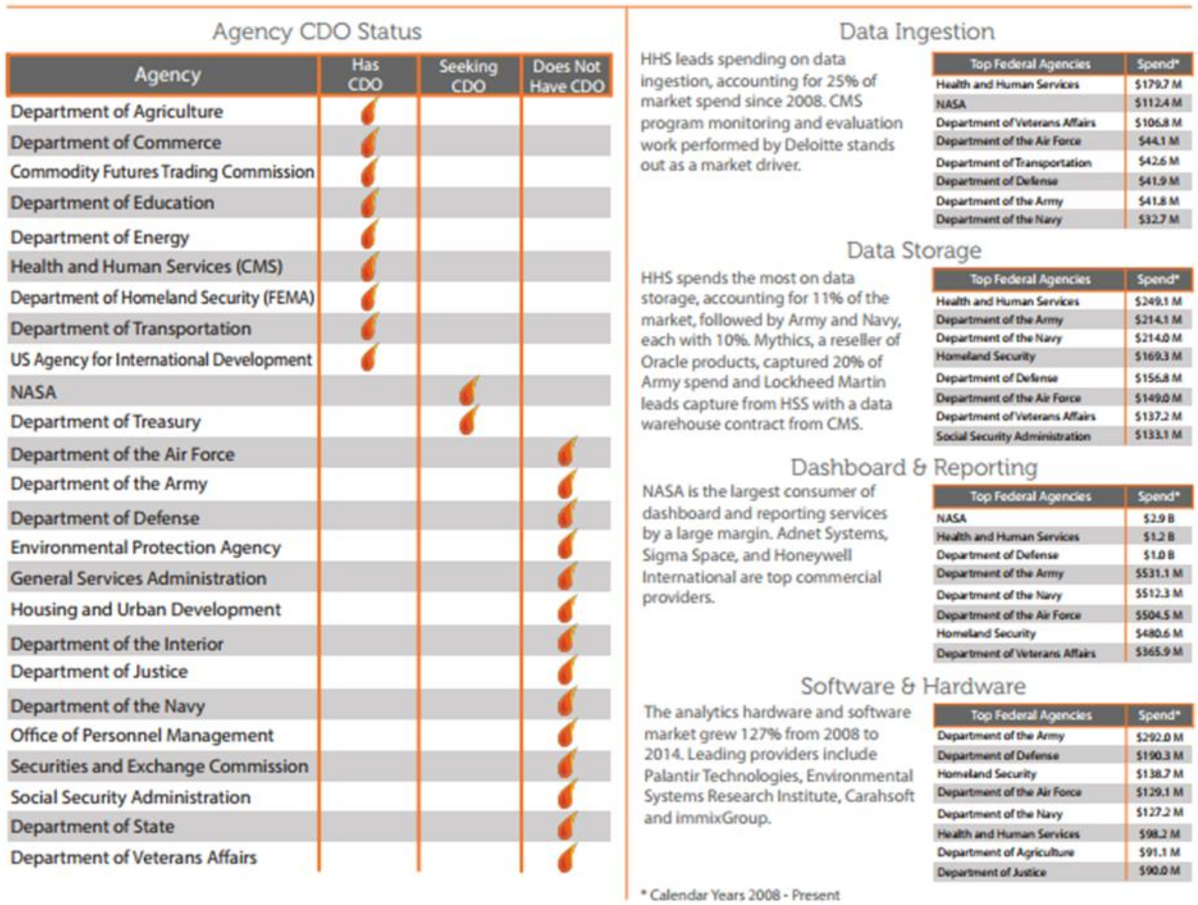

Figure 7. Federal Chief Data Officer Information (Noble, 2016)

Industry Collaboration

Harnessing the synergy from working with industry partners is critical to the successful implementation of IT within the Air Force. “[Industry] partnerships are predicated on the notion that governments today simply lack the requisite knowledge, skills and financing to provide core public services and acquire sophisticated services, IT and knowledge development by themselves. [...] There is a positive relationship between

SCT utilization and firm performance, and this increases when the level of information sharing between supply chain partners increases" (Zhongzhi et al., 2016).

In the Department of Defense Information Technology Environment's *2020 Way Forward to Tomorrow's Strategic Landscape* document, they identified eight specific goals. Goal #2 focuses on, "Improving Partnerships with Allies and Industry" (2020 Way Forward, 2015).

> **Mission Impact:** Positive synergies in processes, technologies, and intellectual capital are mutually beneficial to DoD and its partners.
>
> . Objective 1: Partner Better with Industry
>
> . Objective 2: Enable Information Sharing and Enhance Collaboration with Key Allies and Partners to Simplify Capabilities and Readiness
>
> . Objective 3: Provide the Mission Partner Environment – Information System (MPE-IS)
>
> . Objective 4: Streamline the Technology Approval Process

Collaboration with industry partners touches on more than just Objective #2 in Goal #2 (see Appendix V).

In the Special Interest Group on Computer Personnel Research (SIGCPR) Proceedings of the 1999 ACM SIGCPR Conference on Computer Personnel Research, Critical Success Factors in Enterprise Wide Information Management Systems Projects, "the [implementation] team should have a mix of consultants and internal staff so the internal staff can develop the necessary technical skills for design and implementation" (Sumner, 2017). The SAF/CIO agreed in the *Air Force Information Dominance Flight Plan*, stating that, "innovation alone will not enable information dominance. Rapid and agile acquisition is critical to ensuring information technology and operational technology can respond to dynamic cyberspace requirements. Best practices from industry and mission partners should quickly be integrated into the Air Force cyberspace enterprise" (SAF/CIO A6, 2017).

Validity of Theory Selection

Appropriateness of the Diffusion of Innovations Theory in this study is supported by results from the Data Collection section. Consistency is exemplified in the concept of educating the workforce, which theory notes as a major factor of entities in the late majority. Additional research also supports the validity of categorization the U.S Air Force as a member of the late majority. Supporting evidence was found stating that the U.S. Air Force was seeking to implement information technologies into its supply chain (1) due to economic pressures of constrained resources and the need for efficiency and (2) peer pressures (e.g. constrained resources and shrinking capability gaps).

Air Force Implications

The implication for the U.S Air Force this research provides is the knowledge of current factors that are deemed as critical to success for future IT-based implementation efforts. Propositions regarding policy, workforce education, investment, and industry partner collaboration identify four factors that should be part of the framework for assessing new IT-based supply chain initiatives. Policies should be firm but flexible and clearly communicated. Special attention should be paid to policy's impact on culture. Additionally, new IT-initiatives should encompass a strategic plan for workforce education. Initiatives must be invested in more than on a financial level; emotional investment and support from senior leadership was also noted as critical. Finally, collaboration with industry partners was noted as important in literature and was supported in U.S. Air Force and DoD published documents. Working with industry partners is important, affording synergistic relationships and allowing for lessons learned and best practices data.

Further Research Opportunities

With advances in technology affecting the supply chain so greatly, there is exponential opportunity for elaboration on the topic of technology's impact on the supply chain. One research stream in particular includes the study of how additive manufacturing (AM) will transform existing inventory, purchasing, and workflow processes. Techniques addressed in this thesis including Six Sigma and Lean can potentially be transformed completely, seeing major factors like "Just in Time" (JIT) inventory strategies as "Made in Time" or "Built in Time" components. Additional research opportunities also lie within the unresearched factors noted as critical to success that were not captured in the four selected factors due to scope.

APPENDIX A

IIoT Country Initiatives (Louchez, 2016)

APPENDIX B

Diffusion of Innovation Theories

Citation	Theory Applied							
	Diffusion of Innovation	Expectancy-Value Theory	Grounded Theory	Cultural Dimensions Theory	Institutional Theory	Theory of Planned Behavior	Theory of Reasoned Action	Unified Theory of Acceptance
(Collerette et al., 2003)	x	x					x	x
(Kayworth and Leidner, 2006)	x					x	x	
(Martins and Oliveria, 2011)	x				x	x		x
(Todd and Wixom, 2005)	x		x	x				

APPENDIX C

Review of Critical ERP Implementation Success Factors (Nah et al., 2001)

	ERP teamwork and composition	Change management program and culture	Top management support	Business plan and vision	BPR and minimum customization	Effective communication	Project management	Software development, testing and troubleshooting	Monitoring and evaluation of performance	Project champion	Appropriate business and IT legacy systems
Bingi *et al.* (1999)	X	X	X		X			X			
Buckhout *et al.* (1999)	X		X	X							
Falkowski *et al.* (1998)	X	X		X		X	X		X	X	
Holland *et al.* (1999)	X	X	X	X	X	X	X	X	X		X
Roberts and Barrar (1992)		X	X	X	X				X		X
Rosario (2000)	X	X		X	X	X	X	X	X	X	
Scheer and Habermann (2000)								X			
Stefanou (1999)	X									X	
Sumner (1999)	X	X	X		X	X	X		X	X	
Wee (2000)	X	X	X	X	X	X	X	X			

APPENDIX D

Data Analysis

	Accurate Input Data	Effective Communication	Global Mindset	Implementation Team	Industry Collaboration	Leadership Support	Policy / Culture	Plan / Vision	Software	Structure	Workforce Education
IIoT Summit	x		x		x	x	x	x		x	x
Nah et al., 2001		x		x		x	x	x	x		
Somers and Nelson, 2001		x		x	x	x		x	x		x
Umble et al., 2003	x	x		x		x	x				x
Françoise et al., 2009		x		x		x	x	x	x		

APPENDIX E

DoD Information Technology Environment's *2020 Way Forward to Tomorrow* (JCS, 2000)

Information Access		
Objective 2.1 –Optimize AF Information and Intelligence Networks. (COMPUTE/STORE)	**SMP Links**	**OPR**
Challenge: The Air Force Information Network (AFIN), ISR and other domains are characterized by duplicative capabilities plagued by vulnerabilities, incompatibilities, and excess costs. Air Force missions demand IT services to execute core missions. Vector: The Air Force must harness cloud computing, commodity and enterprise IT services, leverage DoD and IC capabilities to increase mission effectiveness and cybersecurity while reducing costs. Action: Evaluate, resource, and employ cloud services that enable mission assurance. Host limited Air Force specific applications when required to meet the needs of Air Force core missions. Avoid development of unique Air Force application solutions; employ industry/commercial solutions. Evaluate, resource, and employ software, platform, and infrastructure "as a service" solutions that focus on mission assurance and cyber security of Air Force core missions. Consolidate duplicative and interrelated systems into a single enterprise level capability. The Air Force will migrate from legacy technology where operationally relevant (i.e. Joint Information Environment adoption).	AG2.1 FH1.1 FH1.3 FH2.2 FH2.4 FH2.7 ISR.1 ISR.2 ISR.3	SAF/CIO A6S
Objective 2.3 – Assure the availability, integrity and confidentiality of information in cyberspace. (PROTECT)	**SMP Links**	**OPR**
Challenge: Airmen require accurate and secure information to execute Air Force core missions. Vector: Information in cyberspace must be protected commensurate with its classification and value to national security. The complexity of securing information that resides or passes through Air Force systems, including networks, weapon systems, and space systems, requires protection and mitigation from threats. Action: Air Force must work closely with NSA, OSD, Joint Staff, and industry partners developing aggressive courses of actions to meet cryptographic threats and to develop mitigating actions that ensure critical information and weapon systems remain secure and free to operate in cyber contested environments.	AG2.1 FH1.1 FH1.3 FH2.4 IN3.3 ISR.1 ISR.2 ISR.5	SAF/CIO CISO

ORGANIZE, TRAIN & EDUCATE		
Objective 3.3 - Enhance cyberspace education and training for all Airmen.	**SMP Links**	**OPR**
Challenge: All Airmen must understand the importance and inherent risks cyberspace poses to the AF core missions and how their actions in cyberspace impacts those missions. All Airmen must understand the need to be proactive and vigilant to protect against cyber threats. Vector: Every Airman across the Total Force will understand how their actions impact cybersecurity. Through training and education, Airmen will understand the consequences of cyberspace threats, anticipate and mitigate them through personal and collective behavioral changes and actions resulting in every Airmen equipped with a cybersecurity mindset. Action: Transform all academic curricula by embedding cybersecurity into the Air Force lexicon, doctrine and culture. Collaborate with joint, inter-agency and industry partners on best practices and shared challenges to create innovative approaches to cyber education and training for all Airmen. Embed the construct into every DoD institution and reiterate it with strategic communication.	AG1.1 AG1.2 AG1.3 AG1.4 AG3.3 GCT.1 IN2.3 MDA.1 MDA.2	SAF/CIOCISO AF/A2D (OCR)
Objective 3.4 – Increase mission focused cyberspace education and training for cyber Airmen.	**SMP Links**	**OPR**
Challenge: Cyber Airmen must obtain and maintain the skills and knowledge that make them experts, not only in cyber, but also in the Air Force core missions they support.19 Operational success in the cyber environment requires cyber Airmen with a comprehensive understanding of the mission platforms they operate and sustain, the risks to mission success imposed by system architectures and processes, and the knowledge and determination to recommend and execute changes that mitigate those risks. Vector: Train and educate cyber Airmen on cyberspace and its importance to mission assurance of Air Force core missions. The Air Force will minimize the time from requirement to delivery for new cyber training and education needs, and the time investment necessary to complete training and education. The Air Force will institutionalize education on mission assurance and training on functional mission analysis. Action: Leverage agile, integrated, and dynamic institutional learning centers that are responsive to evolving technologies and capabilities. Consolidate and/or integrate common platform/mission-specific education pipelines. Employ live, virtual and constructive integrated training environments (LVC-ITE) to raise proficiencies, integrate, and increase capacity to develop cyber Airman. Explore viable total force integration solutions to bridge instructional capacity shortfalls. Collaborate with joint, inter-agency and industry partners on best practices to create a comprehensive, shared learning environment.	AG1.2 AG1.3 AG1.4 AG3.3 GCT.1 IN2.3 MDA.1 MDA.2	SAF/CIOA6S AF/A2D (OCR)

CAPITAL INVESTMENT		
Objective 4.2 – Develop and Implement a comprehensive Air Force cyberspace and IT portfolio management process.	**SMP Links**	**OPR**
Challenge: The Air Force does not currently have or use efficient capital planning and investment control, or effective IT portfolio management tools and processes. The Air Force spends $4B to $20B annually on cyber / IT-related systems, and does not manage that spend in a single, holistic portfolio view. If we are to deliver better capabilities faster and effectively control IT spending, we must have industry best practice processes and tools in use to inform investment decisions and governance. Vector: The Air Force will leverage best practices across all mission areas and functional managers to better manage its overarching information technologies (IT)/operational technologies (OT) portfolio. Action: Develop and Implement a cyberspace and IT portfolio management process. Develop and implement portfolio management processes that account for and deliberately co-manage all cyber / IT spends across the various stovepipes. The process must be governed by a formalized investment review board that informs the Strategic Planning and Programming Process (SP3). Ensure IT/OT investments comply with the overall Air Force Enterprise Architecture (EA).	AG2.1 AG2.3 AG2.5 FH2.1	SAF/CIO A6X SAF/AQ (OCR)
Objective 4.3 – Develop adaptable, affordable and agile processes to leverage industry partners to accelerate cyberspace capabilities to the warfighter.	**SMP Links**	**OPR**
Challenge: The Air Force must continually refine, improve, and increase the speed of acquisition to keep pace with dynamic demands of the information environment. Conversely, adversaries operating in the information environment have unconstrained access to technology that provides them with an asymmetrical operational advantage which threatens our national security. Vector: The Air Force will leverage idea sharing between government and private sectors. It will leverage talents in the private sector and industry to deliver capabilities through a more agile acquisition process. Action: The Air Force will seek new and agile processes to deliver rapid requirements and capabilities to assist the acquisition community in delivering cyber resilient weapon systems to the warfighter. We will leverage industry partners, experimental, innovation, and emerging rapid acquisition vehicles to deliver capabilities with agility and speed. We will proactively prototype capability, and immerse ourselves in over-the-horizon technology that if/when implemented drives costs down and delivers secure and resilient capabilities to the warfighter.	AG2.1 AG2.2 AG2.3 AG2.4 AG2.5 AG3.3 FH2.1 GCT.2 INI.3	SAF/CIO A6X SAF/AQ (OCR)
Objective 4.4 – Unify cyberspace investment requirement priorities across the Air Force within the Strategy, Planning, and Programming Process (SP3).	**SMP Links**	**OPR**
Challenge: The Air Force must proactively identify, plan and program responses to cyberspace capability shortfalls in fiscal year defense planning systems. Vector: The Air Force operates in an information environment where change is constant. To counter the emerging cyber threats, we must be postured to dynamically and rapidly respond, both operationally and within the acquisition community. This drives shifts to the AF investment priorities within the AF cyberspace portfolios. Given the dynamic nature of the cyberspace investments, the Air Force must proactively assess the risks to missions, leverage holistic and predictive analysis, and posture adaptive governance processes that are flexible enough to reprioritize resources. Action: The Air Force will assess risks to dynamic investments through proactive analysis using frameworks like Non-secure Internet Protocol Router Network (NIPRNET) and Secret Internet Protocol Router Network (SIPRNET) Cybersecurity Architecture Review (NSCSAR). We will work with DoD, acquisition, and federal partners to seek agile, interoperable, mutually beneficial, combined acquisition programs to deliver IT and cyber capability requirements to assist the acquisition community in delivering cyber resilient weapon systems to the warfighter.20 Use catalysts such as Defense Innovation Unix Experiment (DIUX) to identify and develop solutions between government and industry to deliver rapid capability to the warfighter.	AG2.1 AG2.2A G2.3 AG2.4 AG2.5 AG3.3 GCT.2 INI.3	SAF/CIO-A6X AF/A5-8 (OCR)

APPENDIX F

Sample Industrial Internet of Things (IIoT) Coordination Meeting Minutes

IIoT Event Coordination
Meeting Minutes
June 20, 2016

Present: Dr Paul Hartman, Ms Lynn Moad, Mr Bob Fudge, Mr Brian Cunningham, Ms Pam Bartlett, Mr Chris Sharbaugh, Mr Brad Rhoton, Ms Jessica Smith, Mr Matthew Mangen

Next meeting: July 11, 2016 – 10:30AM
On-site: AFIT Building 641, Room 230 D
Meet-Me Number: (***) ***-****

- PTC provided draft event release (attached separately) with information on event description, graphics, technical sponsors, etc. – this will need to be refined with specific details for the 13-14 Dec IIoT event

- Agreement that the overarching theme is to inform USAF senior leaders on "IIoT" art of the possible

- PTC discussed several hands-on demo participants:
    - Caterpillar: Hands on display utilizing augmented reality with a generator (from their Thingworx Live event)
    - GE: Robotic arm demo

- Discussion on morning keynote speaker: Dr Michael Porter from Harvard Business Review – PTC took the action to confirm availability; PTC to send Dr Porter's bio and an article to Paul Hartman

- Discussion on afternoon keynote speaker: Jim Heppelmann, PTC CEO, focusing on IIoT and Cyber Security – PTC took the action to confirm availability

- Other demo participants to be contacted:
    - Microsoft – PTC took the action
    - Google – Evanhoe took the action
    - Boeing – Paul Hartman took the action
    - Pratt & Whitney – PTC took the action
    - Lockheed Martin – Paul Hartman took the action
    - Emerson (wearables) – Chris Sharbaugh and Evanhoe took the action
    - Flowserve (energy) – PTC took the action

APPENDIX G

2016 IIoT Summit Agenda

Industrial Internet of Things (IIoT) Summit:
Harnessing the Power of Data to Achieve Third Offset Effects

Hosted by the Air Force Institute of Technology – Center for Operational Analysis

Bane Hall, Thursday, 15 December 2016

Badge Pickup and Breakfast	0730-0800	All Attendees
Welcome and Administrative Remarks	0800-0830	Dr Todd Stewart Mr Kevin Williams
IIoT and the DoD Enterprise *Enabling Third Offset Effects*	0830-0900	Dr Paul Hartman Mr Harry Foster
Break *Assemble Panel Members*	0900-0915	
Facilitated Panel Discussion #1 *"What is IIoT: Past, Present, and Future?"*	0915-1015	Dr Paul Hartman

Panel #1 Members:

Mr Scott Dewicki, Enterprise Supply Chain Practice Lead, Gartner

Mr Chuck Evanhoe, President of Evanhoe & Associates, Inc.; Chairman of IoT10, the U.S. Technical Committee for ISO/IEC JTC1/WG10—IoT Standards Working Group

Mr Steven Foote, Technical Director, Software Engineering Technical Center, MITRE

Dr Margaret Loper, Chief Scientist and Chief Technologist, Center for the Development and Application of Internet of Things Technologies (CDAIT), Georgia Tech Research Institute

Mr Mark Valentine, Director, U.S. Air Force Strategic Programs, Microsoft

Panel Members will discuss broad perspectives on the advancement of technology and data-driven business functions, addressing questions such as:

a. How are technology-enabled, data-intensive process structures challenging business norms?
   --consider implications to infrastructure investment, manufacturing processes, workforce development, supplier relationships, strategic partnerships, and/or joint ventures.

b. What measures are being taken to prepare for inclusion of advanced data-intensive automation and robotics across ‘connected’ enterprises?
   --consider requirements associated with integrating the following capabilities:

   1. Assisted Human Operations
   2. Autonomous Learning Systems
   3. Human-machine Collaboration
   4. Human-machine Combat Teaming
   5. Network-enabled, Semi-autonomous Technology

Break 1015-1030

Facilitated Panel Discussion #2 1030-1130 Dr Paul Hartman

“Applying IIoT: Realities and Risks in the DoD Domain”

Panel #2 Members:

Mr Sam Gordy, General Manager, U.S. Federal and Government Industries, IBM

Mr Walt Hearn, Director, ANSYS

Mr Scott Jenkins, VP, North American Sales and Marketing, Yaskawa

Dr Jimmy Kenyon, Senior Director, Advanced Programs and Technology, Pratt & Whitney

Dr Bob Mills, Director, Center for Cyberspace Research

Ms Renee Pasman, Director, ADP Mission System Roadmaps, Lockheed Martin

Panel Members will provide illustrative examples operationalizing IIoT in various industry settings, addressing questions such as:

a. What are the most significant risks associated with investing in the application and use of advanced technologies in IIoT data-driven domains?

--consider effects of technology advancement, technology antiquation, cyber security, cloud-based technology, workforce skilling

b. What ‘lessons learned’ have been observed to date and what future problem sets should be considered now in preparation for tomorrow’s IIoT resource investments?

No-host Catered Lunch *Atrium, Bldg 646, Rm 103*	1130-1215	
IIoT Summit Keynote Speaker *Bane Auditorium, Bldg 640, Rm 248*	1215-1245	Mr Jim Heppelmann PTC, CEO
Introduction of IIoT Demonstrations	1245-1300	Mr Brent Baker PTC, VP
Break and Transition	1300-1315	
Industry Partner IIoT Demonstrations	1315-1345	Ansys, Caterpillar, IBM, Microsoft, PTC
Break and Transition	1345-1400	
Industry Partner IIoT Demonstrations	1400-1430	Ansys, Caterpillar, IBM, Microsoft, PTC
Break and Transition	1430-1445	
Industry Partner IIoT Demonstrations	1445-1515	Ansys, Caterpillar, IBM, Microsoft, PTC
Break and Transition	1515-1530	
Industry Partner IIoT Demonstrations	1530-1600	Ansys, Caterpillar, IBM, Microsoft, PTC
Break and Transition	1600-1615	
Facilitated USAF Senior Leadership Panel *“IIoT and Third Offset Effects”*	1615-1700	Dr Paul Hartman

Bibliography

2046 Strategic Plan. U.S. Army, 2 August 2016.

Air Force Logistics Management Agency. "Year in Review: Generating Solutions Today, Shaping Tomorrow's Logistics," *Air Force Journal of Logistics*, (2003).

Air Force Studies Board. *Examination of the U.S Air Force's Aircraft Sustainment Needs in the Future and Its Strategy to Meet Those Needs*. The National Academic Press, 2011.

Allred, Chad, Amydee M. Fawcett, Stanley E. Fawcett, Gregory Magnan and Cynthia Wallin. "Information Technology as an Enabler of Supply Chain Collaboration: A Dynamic-Capabilities Perspective," *Journal of Supply Chain Management*, 47.1:38-59 (2011).

"AMC, PEO Ground Combat Systems Eliminate Redundancies in Stryker Retrograde." *www.army.mil*. U.S. Army. 23 July 2013. Accessed 14 July 2017. Web.

Anbari, Frank T. and Young H. Kwak. "Benefits, Obstacles and Future of Six Sigma Approach," *Technovation*, 26:708-715 (2006).

Antony, Jiju and Ricardo Banueles. "Key Ingredients for the Effective Implementation of Six Sigma," *Measuring Business Excellence*, 6.4:20-27 (2002).

Arkes, Jeremy and Mary E. Chenoweth. "Estimating the Benefits of the Air Force Purchasing and Supply Chain Management Initiative." *www.rand.org*. RAND. 2008. Accessed 24 July 2017. Web.

Autry, Chad W., Tyler R. Morgan and Robert Glenn Richey Jr. "Developing a Reverse Logistics Competency: The Influence of Collaboration and Information Technology," *International Journal of Physical Distribution & Logistics Management*, 46.3:293-315 (2016).

Bailey, John W., Marilee O. Cunningham, Graeme R. Douglas, Dawn M. Floyd, Anthony Insolia, Paul K. Ketrick and Laura A. Odell. "Assessment of DoD Enterprise Resource Planning Business Systems." *www.acq.osd.mil*. Institute for Defense Analyses. February 2011. Accessed 28 August 2017. Web.

Bird, Kate. “Impact Assessment: An Overview.” *www.odi.org.* Overseas Development Institute. 2006. Accessed 14 July 2017. Web.

Brake, Terence. "Human Machine Collaboration." *www.trainingmag.com*. Training Magazine. 23 June 2015. Accessed 10 January 2017. Web.

"Breakthrough Ideas for 2006." *www.hbr.org*. Harvard Business Review. February 2006. Accessed 20 August 2017. Web.

Brun, Alessandro, Annachiara Longoni, Davide Luzzini and Antonella Moretto. "Organizing IT Purchases: Evidence from a Global Study," *Journal of Purchasing and Supply Management*, 20.3:143-55 (2013).

Carroll, John M., Ernesto Damiani, Miltiadis D. Lytras, Patricia Ordonez De Pablos, Robert D. Tennyson and Gottfried Vossed. "The Open Knowledge Society," Proceedings of the First World Summit on the Knowledge Society. 2008.

Cenciotti, David. "U.S. Air Force Plans to Remove Almost 500 Aircraft over the Next Five Years." *www.theaviationist.com*. The Aviationist. Accessed 5 April 2017. Web.

Charette, Robert N. "U.S. Air Force Blows $1 Billion on Failed ERP Project." *www.spectrum.ieee.org*. IEEE. 15 November 2012. Accessed 5 April 2017. Web.

Choo, Adrian S., Kevin Linderman, Roger G. Schroeder and Srilata Zaheer. "Six Sigma: A Goal-theoretic Perspective," *Journal of Operations Management*, 21.2:193-203 (2003).

Coghlan, David and Paul Coughlan. “Action Research for Operations Management,” *International Journal of Operations & Production Management*, 22.2:220-240 (2002).

Comptroller General of the United States. *Decision*. U.S. Government Accountability Office, 1 March 2017.

"Condition Based Maintenance Plus (CBM+)." *www.acq.osd.mil*. Office of the Assistant Secretary of Defense for Logistics & Materiel Readiness. Accessed 20 July 2017. Web.

"Condition Based Maintenance Plus (CBM+)." *www.dap.dau.mil*. Defense Acquisition University. Accessed 20 July 2017. Web.

Dobbs, Richard, Katy George, David O'Halloran, James Manyika, Jan Mischke, Sreenivas Ramaswamy, Jaana Remes, Charles Roxburgh and Jeff Sinclair. "Manufacturing the Future: The Next Era of Global Growth and Innovation." *www.mckinsey.com*. McKinsey & Company. November 2012. Accessed 20 July 2017. Web.

Eaglen, Mackenzie. "What is the Third Offset Strategy?" *www.aei.org*. American Enterprise Institute. 16 February 2016. Accessed 20 July 2017. Web.

"eLog21 Fact Sheet - Expeditionary Combat Support System." *www.acc.dau.mil*. U.S. Air Force. Accessed 4 April 2017. Web.

"eLog21 Fact Sheet - Purchasing & Supply Chain Management." *www.acc.dau.mil*. U.S. Air Force. Accessed 4 April 2017. Web.

Elsinga, Christian, Marjo Heikkilä, Sikke de Jong and Sakari Pieskä. "Experimenting Industrial Internet with a Mobile Robot: Expanding Human Cognitive Functions," Proceedings of the 6th IEEE International Conference on Cognitive Infocommunications. 2015.

Estimated Impacts of Sequestration-Level Funding. Department of Defense, April 2014.

"Evolution of SCL, The." *www.scl.gatech.edu*. Georgia Tech Supply Chain & Logistics Institute. Accessed 20 July 2017. Web.

"Expeditionary Logistics for the 21st Century (eLog21)." *www.af.mil*. U.S. Air Force. Accessed 4 April 2017. Web.

Fawcett, Amydee M., Stanley E. Fawcett, Yao Henry Jin and David Swanson. "Collaborative Process Design: A Dynamic Capabilities View of Mitigating the Barriers to Working Together," *International Journal of Logistics Management*, 28.2:571-599 (2017).

Fine, Charles H. and David Simchi-Levi. "Your Next Supply Chain." *www.sloanreview.mit.edu*. Massachusetts Institute of Technology. 1 January 2010. Accessed 20 July 2017. Web.

Flynn, Anna, P. Fraser Johnson and Michiel Leenders. *Purchasing and Supply Management (14th edition)*. New York: McGraw-Hill, 2011.

Grier, Peter. "The First Offset," *Air Force Magazine*, 56-60 (June 2016).

Haft, Ronald R., Elisabeth J. Umble and M. Michael Umble. "Enterprise Resource Planning: Implementation Procedures and Critical Success Factors," *European Journal of Operational Research*, 146.2:241-257 (2003).

Harper, John. "Air Force to Eliminate Nearly 500 Aircraft in 25 states, D.C. and Overseas." *www.stripes.com*. Stars and Stripes. 11 March 2014. Accessed 4 April 2017. Web.

"Industrial Internet of Things Summit." WPAFB, OH. 15 December 2016.

"Information Dominance Vision." *www.safcioa6.af.mil*. Secretary of the Air Force. 2017. Accessed 20 July 2017. Web.

Jin, Alan, Lifang Wu, David C. Yen and Xiaohang Yue. "Smart Supply Chain Management: A Review and Implications for Future Research," *International Journal of Logistics Management*, 27.2:395-417 (2016).

Joint Chiefs of Staff. "Joint Capabilities Integration and Development System." *www.jcs.mil*. Chairman of the Joint Chiefs of Staff. 23 January 2015. Accessed 14 July 2017. Web.

Joint Chiefs of Staff. *Joint Concept for Logistics Version: 2.0*. 5 September 2015.

Joint Chiefs of Staff. *Joint Vision 2020*. Defense Technical Information Center, 2000.

Kaminski, June. "Diffusion of Innovation Theory," *Canadian Journal of Nursing Informatics,* 6.2 (2011).

Karas, Rachel. "Air Force mulling chief data officer position." *www.insidedefense.com*. 7 June 2017. Accessed 20 July 2017. Web.

Kim, Dong-Young. "Relationship Between Supply Chain Integration and Performance," *Operations Management Research*, 6.1:74-90 (2013).

Knemeyer, Michael A., John E. Mello, John P. Saldanha and T.A.S. Vijayaraghavan. "Implementing Supply Chain Technologies in Emerging Markets: An Institutional Theory Perspective," *Journal of Supply Chain Management*, 51.1:5-26 (2015).

Lange, Katy. "3rd Offset Strategy 101: What it is, what the Tech Focuses Are." *www.dodlive.mil*. Department of Defense. 30 March 2016. Accessed 14 July 2017. Web.

Lin, Hsiu-Fen. "Antecedents and Consequences of Electronic Supply Chain Management Diffusion: The Moderating Effect of Knowledge Sharing," *International Journal of Logistics Management*, 28.2:699-718 (2017).

"LogEA Fact Sheet." *www.acc.dau.mil*. U.S. Air Force. Accessed 4 April 2017. Web.

Louchez, Alan. "The Internet of Things Overview and Importance in National Manufacturing Strategies in the U.S. and Abroad." Atlanta, GA. 2 November 2016

Martyn, Paul. "Five Supply Chain Predictions For 2016." *www.forbes.com*. Forbes. 15 December 2015. Accessed 4 April 2017. Web.

Noble, Zach. "FAA joining the chief data officer movement." *www.fcw.com*. Business of Federal Technology. 13 June 2016. Accessed 14 July 2017. Web.

Oke, Adegoke, Daniel Prajogo and Zhongzhi Liu. "Supply Chain Technologies: Linking Adoption, Utilization, and Performance," *Journal of Supply Chain Management*, 52.4:22-41 (2016).

"PCSM Fact Sheet 4 (What Does PCSM Mean)." *www.acc.dau.mil*. U.S. Air Force. 18 August 2004. Accessed 5 April 2017. Web.

Pellerin, Cheryl. "Learning Systems, Autonomy and Human-Machine Teaming." *www.science.dodlive.mil*. DoD News. 13 November 2015. Accessed 14 July 2017. Web.

Porter, Michael E. and James E. Heppelmann. "How Smart, Connected Products Are Transforming Companies." *www.hbr.org*. Harvard Business Review. October 2015. Accessed 14 July 2017. Web.

Porter, Michael E. and James E. Heppelmann. "How Smart, Connected Products Are Transforming Competition." *www.hbr.org*. Harvard Business Review. November 2014. Accessed 14 July 2017. Web.

Robinson, Adam. "Supply Chain Trends to Watch Out for in 2016." *www.cerasis.com*. Cerasis. 5 January 2016. Accessed 4 April 2017. Web.

Rogers, Everett. "Diffusion of Innovations." *www.web.stanford.edu*. 1995. Accessed 13 April 2017. Web.

Secretary of the Air Force Public Affairs. "Air Force Releases Strategic Master Plan." *www.af.mil*. U.S. Air Force. 21 May 2015. Accessed 4 April 2017. Web.

Shah, Rachna and Peter T. Ward. "Lean Manufacturing: Context, Practice Bundles, and Performance," *Journal of Operations Management*, 21.2:129-149 (2002).

Singh, Mahender. "Future-focused Supply Chains: Supply Chain Strategies Shaped by the Future." *www.ctl.mit.edu*. MIT Center for Transportation & Logistics. Accessed 20 July 2017. Web.

Sirota, Sara. "Top General: Today's Air Force 'Smallest We've Ever Been.'" *www.thehill.com*. The Hill. 24 February 2017. Accessed 10 April 2017. Web.

"State of the Air Force press briefing by Secretary James and General Welsh." *www.defense.gov*. Department of Defense. 15 January 2015. Accessed 10 April 2017. Web.

Strategic Planning Weaknesses Leave Economy, Efficiency, and Effectiveness of Future Support Systems at Risk. Report to Congressional Committees. U.S. Government Accountability Office, October 2001.

"Strategy & Information Technology." *www.isc.hbs.edu*. Harvard Business School. Accessed 14 July 2017. Web.

Subcommittee on Investigations. *The Air Force's Expeditionary Combat Support System (ECSS): A Cautionary Tale on the Need for Business Process Reengineering and Complying with Acquisition Best Practices*. U.S. Senate, 7 July 2014.

Sumner, Mary. "Critical Success Factors in Enterprise Wide Information Management Systems Projects," Proceedings of the 1999 ACM SIGCPR Conference on Computer Personnel Research. 1999.

Todd, Peter and Barbara Wixom. "A Theoretical Integration of User Satisfaction and Technology Acceptance," *Information Systems Research*, 16.1:85-102 (2005).

Toews, David. "Sociology after the End of the Social Theory Culture & Society," *Sage Journals*, 20.5:81-98 (2003).

Transformation Planning Guidance. Department of Defense, April 2003.

"Way Forward to Tomorrow's Strategic Landscape." *www.dodcio.defense.gov*. Department of Defense. August 2016. Accessed 20 July 2017. Web.

Work, Robert O. "Excellence in Public Administration and Distinguished Civilian Service Awards Ceremony." Washington, D.C. 8 October 2015.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
14-09-2017

2. REPORT TYPE
Master's Thesis

3. DATES COVERED *(From - To)*
Mar 2016 - Sep 2017

4. TITLE AND SUBTITLE
Supply Chain Transformation: An Information Technology Perspective

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Smith, Jessica A., Ms.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way
WPAFB, OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT-ENS-MS-17-S-065

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Materiel Command
4375 Chidlaw Road, WPAFB OH 45433
Ms.Kim M. Brown, DAF Requirements Branch Chief
Kim.Brown@us.af.mil

10. SPONSOR/MONITOR'S ACRONYM(S)
HAF/A4PT

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Statement A. Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Since the early 2000s, the U.S. Air Force Logistics Community has invested in multiple high-level strategic programs and related information technology (IT) initiatives in attempt to significantly improve global supply chain practices. Unfortunately, strategic programs such as the Expeditionary Logistics for the 21st Century and its associated initiatives had limited success and failed to produce desired improvements. In order to remain competitive in the evolving global warfighting environment and to fulfill Third Offset requirements, it is important for the U.S. Air Force Logistics Community to use lessons-learned in its own IT-enabled supply chain transformation history, as well as industry best practices and lessons-learned to effectively harness the power of advanced information technologies. The purpose of this research is to examine U.S. Air Force and industry supply chain IT-enabled transformations to identify critical factors for the successful adoption of new supply chain technologies. Based on the findings from a review of existing literature and semi-structured interviews with eleven subject matter experts, four propositions have been developed as a suggested framework for the U.S. Air Force Logistics Community to consider when evaluating potential supply chain-related information technology initiatives. The four propositions were identified as important aspects for successful IT implementation by literature and selected interviewees regarding policy, workforce education, investment, and industry collaboration.

15. SUBJECT TERMS
Information Technology, Supply Chain, Critical Success Factors, U.S. Air Force

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	71	Dr. Paul Hartman AFIT/ENS
					19b. TELEPHONE NUMBER *(include area code) (937) 785-3636 ext 4521 Paul.Hartman@afit.edu*